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Allophane on Mars: Evidence from IR spectroscopy and TES spectral models

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Allophane is an alteration product of volcanic glass and a clay mineral precursor that is commonly found in basaltic soils on Earth. It is a poorly-crystalline or amorphous, hydrous aluminosilicate with Si/Al ratios ranging from ~ 0.5 -1 [Wada, 1989]. Analyses of thermal infrared (TIR) spectra of the Martian surface from TES show high-silica phases at mid-to-high latitudes that have been proposed to be primary volcanic glass [Bandfield et al., 2000; Bandfield, 2002; Rogers and Christensen, 2007] or poorly-crystalline secondary silicates such as allophane or aluminous amorphous silica [Kraft et al., 2003; Michalski et al., 2006; Rogers and Christensen, 2007; Kraft, 2009]. Phase modeling of chemical data from the APXS on the Mars Exploration Rover Spirit suggest the presence of allophane in chemically weathered rocks [Ming et al., 2006]. The presence of allophane on Mars has not been previously tested with IR spectroscopy because allophane spectra have not been available. We synthesized allophanes and allophanic gels with a range of Si/Al ratios to measure TIR emission and VNIR reflectance spectra and to test for the presence of allophane in Martian soils.

VNIR reflectance spectra of the synthetic allophane samples have broad absorptions near 1.4 μm from OH stretching overtones and 1.9 μm from a combination of stretching and bending vibrations in H_2O . Samples have a broad absorption centered near 2.25 μm , from AlAlOH combination bending and stretching vibrations, that shifts position with Si/Al ratio. Amorphous silica (opaline silica or primary volcanic glass) has been identified in CRISM spectra of southern highland terrains based on the presence of 1.4, 1.9, and broad 2.25 μm absorptions [Mustard et al., 2008]; however, these absorptions are also consistent with the presence of allophane.

TIR emission spectra of the synthetic allophanes show two spectrally distinct types: Si-rich and Al-rich. Si-rich allophanes have two broad absorptions centered near 1080 and 430 cm^{-1} from Si(Al)-O stretching and Si(Al)-O bending vibrations, respectively, and Al-rich allophanes have three broad absorptions centered near 950, 540, and 430 cm^{-1} . We used a spectral library commonly used to deconvolve TES spectra and four allophane spectra to model nine spectrally distinct regions on Mars [from Rogers et al., 2007]. Regions previously modeled with high-silica phases contain significant amounts of allophane (>10 vol.%) in our models. Our models of northern Acidalia, the type locality for surface type 2 materials, contain 40 vol.% Si-rich allophane. The presence of allophane in multiple surface regions of Mars indicates a more widespread occurrence of low-temperature aqueous alteration at moderate pH than has been previously recognized. The regional variations in modeled abundances and the types of allophane (Si- vs. Al-rich) suggest regional differences in Mars weathering processes.